

CHAPTER

8 Static Pile Load Testing and Dynamic Pile Monitoring

Introduction

Chapter 1 of this manual explained how a foundation investigation for all new structures, widenings, strengthenings or seismic retrofits is performed by the Office of Structural Foundations. Under normal circumstances, the Engineering Geologist assigned to perform the investigation is able to gather enough information to allow them to recommend a pile type and tip elevation that they firmly believe is capable of supporting the required loads on the recommended pile foundation.

On the other hand, there are many situations when the Engineering Geologist is not able to gather the necessary subsurface information that allows them to comfortably recommend a pile foundation that they have complete confidence in. Whenever this occurs, the Engineering Geologist may recommend a Static Pile Load Test or Dynamic Pile Monitoring operation to ensure that the piles are going to perform in the manner predicted in the design of the foundation.

Personnel from the Foundation Testing and Instrumentation Section of the Office of Structural Foundations perform Static Load Testing and Dynamic Pile Monitoring on Caltrans projects. Once the testing is completed, written reports summarizing the findings are transmitted to the Structure Representative.

Reasons For Static Load Testing and Dynamic Pile Monitoring

In order to determine the capacity of foundation piles, the Foundation Testing and Instrumentation Section performs Static Pile Load Testing for all types of foundation piles, and Dynamic Pile Monitoring of driven piles.

Static Load Tests are performed to determine the ultimate failure load of a foundation pile and to determine the pile's capability of supporting a load without excessive or continuous displacement. The purpose of such tests is to verify that the allowable loads used for the design of a pile are appropriate and that the installation procedure is satisfactory. Static load tests also allow for the use of a lower factor of safety and a more "rational" foundation design.

Static load tests may be recommended when foundation piles are being installed in certain locations or types of material where ordinary methods of determining safe pile loads are not considered reliable. They are often recommended for Cast-In-Drilled-Hole (CIDH) piles installed in unproven ground formations. Static Load Testing is also performed where it is desired to demonstrate that friction piles may be safely loaded beyond the indicated safe loads obtained by the application of the Engineering News-Record (ENR) formula. Static Load Tests are also recommended for piles designed to carry loads in tension, particularly those foundation piles used on seismic retrofit projects.

Dynamic Pile Monitoring of driven piles is used to verify and/or predict pile capacities and to gather various pieces of useful information during the installation of driven piles.

Obtaining a successful pile foundation, which meets the design objectives, depends largely on relating the static analysis results presented on the plans to the dynamic methods of field installation.

Static Pile Load Tests

When Static Pile Load Testing is performed on a project, personnel from the Foundation Testing and Instrumentation Section follow the "Quick Load Method" of ASTM D1143 for static load testing in compression, and ASTM D3689 for static load testing in tension. Both the compression and tension load tests require approximately 4 to 8 hours to complete.

The static pile load tests are made using a reaction method. The test procedure involves applying an axial load to the top of the test pile with the use of one or more hydraulic jacks. The reaction force is provided by subjecting the anchor piles to tension, in the case of a static load test in compression; or by subjecting the anchor piles to compression, in the case of a static load test in tension. Various forms of instrumentation are installed onto the test and anchor piles to measure the displacement of the test pile. Redundant systems are used to ensure accuracy of the various measurements.

A five-pile test group (four anchor piles and one test pile) is used for all static load tests in compression and for most tension tests (Refer to Appendix F). Occasionally, a three-pile test group (two anchor piles and one test pile) is used for static load tests in tension (Refer to Appendix F).

Loads are applied in increments usually equal to 10% of the design load. Each increment of load is held for a predetermined time interval. The load increments are applied until the load causes the pile to “plunge”, or up to the point where the capacity of the testing system is reached. The “plunge” point is where little or no additional load is needed to cause the pile to displace.

The Foundation Testing and Instrumentation Section work crews have reaction trusses for static load testing up to 2,000 Tons.

In general, a pile is considered to have failed when the total displacement exceeds $\frac{1}{2}$ inch under load. An acceptable pile is one that reaches double the design load without exceeding the maximum displacement.

The purpose of a Static Pile Load Test is to cause a failure along the soil/pile interface. This failure generally occurs well before the structural capacity of the pile is reached. Once the test is complete, the pile is returned to a no-load condition and can be incorporated into the foundation of a structure. The only permanent effect of the pile load test is the downward displacement of the test pile. The same effect would be achieved if a pile hammer drove the pile the additional distance.

Once the pile load testing is completed, personnel from the Foundation Testing and Instrumentation Section compile and review the load test data. The test data is used to produce a plot of load versus pile displacement. The ultimate capacity of the test pile is determined using graphical or analytical procedures. A summary report is then forwarded to the Structure Representative, along with any recommended changes or modifications, if necessary.

Dynamic Pile Monitoring

Along with Static Load Testing, personnel from the Foundation Testing and Instrumentation Section are assigned the responsibility for performing Dynamic Pile Monitoring on Caltrans projects. In most cases Dynamic Pile Monitoring is performed in conjunction with Static Pile Load Testing.

The dynamic monitoring refers to the use of a device called the Pile Driving Analyzer (PDA). The PDA consists of a portable computer which collects and analyzes strains and accelerations measured by instrumentation attached to the pile being driven.

Dynamic monitoring of piles is usually performed during the installation of the test and/or anchor piles to be used for the Static Load Test. Piles to be monitored, using the PDA, are usually driven to a predetermined distance above the specified tip before the monitoring begins. At that time, the Contractor must stop driving and allow personnel from the Foundation Testing and Instrumentation Section to attach the necessary instrumentation to the pile. This instrumentation is attached approximately $1\frac{1}{2}$ pile diameters from the top of the pile. The Contractor then resumes driving the pile but only for a few blows. This allows the PDA Operator to ensure that the instrumentation is attached correctly and that the data is being transmitted to the PDA computer. The Contractor then resumes driving the pile until the tip of the pile is one foot above the specified tip elevation. Once all the monitored piles are driven to this elevation, they are then allowed to “set-up”, usually overnight. On the next day the instrumentation is once again attached for a retap. Before the retap, the pile must be marked over a one foot length, in increments of one tenth of a foot. Again, the pile is hit for a few blows to ensure proper instrumentation connection. The pile is then driven for the remainder of the one foot length.

Before the pile monitoring begins, the PDA operator inputs parameters related to the physical characteristics of the pile. Data is also entered to describe the surrounding soil and its damping resistance.

The PDA is capable of analyzing the stress wave produced by each blow of the hammer during the driving operation. By analyzing the shape of the wave trace, the PDA is able to measure pile stresses generated during driving. Information retrieved by the PDA is used to predict a pile's static load capacity.

The PDA very accurately measures the energy delivered to the pile during driving. This energy rating can be compared to the manufacturer's rated value to provide an indication of the hammer's actual performance efficiencies. Low or unusual delivery of energy to the

pile may indicate a pre-ignition problem within the hammer, inefficient hammer combustion, misalignment of the follower or helmet, or the use of an inappropriate pile hammer cushion.

During installation, damage to a pile can be detected by the PDA. The data retrieved during the monitoring can be used to locate the depth to cracking in concrete piles and to the point of buckling in steel piles.

Data retrieved from the PDA during the retap of a pile yields valuable information about the soils interaction with the driven pile during a pile's "set-up" period.

Dynamic Pile Monitoring is believed to be very reliable for piles driven in granular soils. For finer grained soils, such as silts and clays, this method is less reliable because these soils offer significantly larger damping resistance to piles during driving that are not yet accurately modeled.

Under normal circumstances, dynamic monitoring is used in conjunction with static load testing to determine the adequacy of foundation piles.

Contract Administration of Static Pile Load Testing and Dynamic Pile Monitoring

At the beginning of any project requiring Static Pile Load Testing and/or Dynamic Pile Monitoring, the Structure Representative should do a thorough review of the project plans, Special Provisions, *Standard Specifications* (Section 49-1.10 in particular), and Bridge Construction Memo 130-1.0 to make themselves aware of the contract requirements.

It is the Structure Representative's responsibility to coordinate the set-up for the Static Pile Load Testing and Dynamic Pile Monitoring. Early contact and good communication with the Foundation Testing and Instrumentation Section is important to ensure that the process flows smoothly. The Contractor's schedule for the installation of the piles should be obtained as early as possible. This schedule should then be forwarded to the Foundation Testing and Instrumentation Section. Details relating to the logistical needs of the testing work crew should also be discussed with the Foundation Testing and Instrumentation Section and the necessary information relayed to the Contractor.

Section 49-1.10 of the *Standard Specifications* requires that a change order be written to compensate the Contractor for the various forms of assistance they will need to provide for

the set-up and performance of the Static Pile Load Testing and/or the Dynamic Pile Monitoring. It should be noted that cutoff of the piles to grade, furnishing additional reinforcing steel and load test anchorages are usually paid for by the contract item for piling.

The Contractor should be notified as early as possible of the equipment and personnel that they will need to provide during a Static Pile Load Test or Dynamic Pile Monitoring operation. The assistance they provide is normally covered by the contract change order that is to be written for the operation.

In general, for a Static Pile Load Test, the Contractor will need to provide a crane and operator for the lifting and placement of the testing equipment off of the State transport trailers, and for returning the equipment to the trailer once the testing is complete. The crane will need to be capable of lifting and placing a 17,000 pound beam atop the pile test groups. Occasionally, a 54,000 pound beam is used for load testing. The actual beam size to be used should be confirmed with the Foundation Testing and Instrumentation Section. All necessary rigging will be supplied by the Foundation Testing and Instrumentation Section. The Contractor will need to provide a welder, welding machine and cutting torches to assist in the installation of the testing equipment. Specific logistical needs and project-specific issues should be discussed with personnel from the Foundation Testing and Instrumentation Section to ensure that efficient coordination of the test set-up is accomplished.

The Structure Representative needs to ensure that the area of the Static Load Testing and/or Dynamic Pile Monitoring is dry and free of debris. A safe working area should be established around the test piles, and any of the Contractor's operations that conflict with the work of the testing work crews should be suspended until the testing is complete.

Section 49-1.10 of the *Standard Specifications* states that no piles may be drilled, cast, cut to length or driven for a structure until the required Static Load Testing is completed.

The *Standard Specifications* also state that Static Pile Load Testing on concrete piles may begin when the concrete reaches a compressive strength of 2,000 Pounds per Square Inch (PSI), except for precast concrete piles, which cannot be driven until 14 days after casting. Additional cement or Type III (high early) cement may be used at the Contractor's expense.

The *Standard Specifications* also state that the Engineer will not require more than 5 working days to perform each test unless otherwise provided in the Special Provisions.

Inspection Requirements During Static Load Testing and Dynamic Pile Monitoring

It is very important that the Structure Representative ensure that all piles to be used for Static Pile Load Testing and Dynamic Pile Monitoring be driven or constructed in accordance with the contract plans and specifications. If the contract plans do not adequately describe the test pile set-up, the Structure Representative should discuss the set-up with the Foundation Testing and Instrumentation Section.

Test piles must be installed plumb and to the specified tip elevation shown on the plans. All piles (anchor and test piles) within each test group should be logged for the full length of driving. For drilled piles, a soil classification record should be kept for the full length of all piles. If any of the driven piles have an extremely low bearing value at the specified tip elevation (less than 50% required), the Structure Representative should contact the Foundation Testing and Instrumentation Section to see if a revision of the specified tip elevation is warranted. Changes to the specified tip elevation on test and/or anchor piles will necessitate the issuance of a contract change order.

For CIDH piles, additional reinforcement is required in the anchor and test piles. This additional reinforcement should be shown on the plans. If it is not shown on the plans or if the details are unclear, contact the Project Designer and/or the Foundation Testing and Instrumentation Section. The top of CIDH test piles must be level and troweled smooth.

The contract plans or Special Provisions usually require that the anchor piles be constructed 5 to 10 feet longer than the test piles to prevent pulling. If this is not shown, the Structure Representative should discuss this issue with the Foundation Testing and Instrumentation Section to determine whether or not the lengths of the anchor piles should be revised. Here again, any changes to the lengths of the piles may warrant a contract change order.

If a construction project includes Dynamic Pile Monitoring, the Special Provisions for the project will state when the piles to be used for the monitoring are to be made available for State personnel to make the necessary preparations before these piles are driven. A technician from the Foundation Testing and Instrumentation Section will need access to the piles to prepare them for the attachment of the necessary instrumentation. The Structure Representative may need to ensure that the Contractor provide assistance to the technician to maneuver the piles.

Once the load testing crew arrives on the jobsite, the Structure Representative will need to have copies of the pile driving logs, soil classification record (for CIDH piles), Log of Test Borings, and Foundation Plan available for their use.

Once the Static Pile Load Testing and/or Dynamic Pile Monitoring is completed on a project, the Foundation Testing and Instrumentation Section will recommend changes to the foundation piles if necessary. These changes are normally made without requiring additional load tests. If an additional test is required, the Structure Representative should be sure to document any delays to the Contractor's operations. If additional testing is required, the State will be responsible for additional costs incurred by the Contractor.

Substantial pile revisions (as a result of poor test results) could have a substantial impact on administrative aspects of the contract. Changes could be such that item prices for pile work are no longer valid and an item price adjustment may be necessary.

Again, it is very important that Structure Representatives set up a good line of communication between themselves and the Foundation Testing and Instrumentation Section in the early stages of the project. The goal should always be to have a clear understanding of what coordination needs to be done in order to properly install the test piles and set up the load testing equipment without significant delays to the project. Good coordination is also important to allow the static load testing work crews from the Foundation Testing and Instrumentation Section to perform the tests efficiently and on schedule.